Introduction to Korean NGV Industry and Hydrogen Blended CNG Project for Coping with EURO 6 Emission

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ABSTRACT

In Korea, NGV was first distributed in 2000 and currently about 32,000 vehicles are running with about 180 refueling stations across the nation. Though the number of vehicles may seem to be small, the growth of NGV is remarkable. Unlike other countries, the heavy duty vehicles such as city buses and trucks have had the principal types of NGV. To expand the number of vehicles, there were strong and effective cooperation between various stakeholders under the definite initiative of the Ministry of Environment.

In the future, to cope with more strong regulation level, NGV parties should make some efforts on new technology to have more competitiveness than other fuels. New type of NGV, called by HCNG vehicle, is currently being developed. Hydrogen blended compressed natural gas(HCNG) vehicles are expected to have some merits such as very low emission and low CO_2 characteristics. In this paper, it will be introduced the status of NGV industry and a HCNG project in Korea.

I. STATUS OF NGV INDUSTRY IN KOREA

1. 1 Natural Gas Vehicles

More than fifteen million NGVs are being operated in worldwide. Pakistan, Iran and Argentina are leading countries in NGV propagation. Approximately two-thirds of worldwide NGVs are operated in top 5 countries. Experience in these countries has shown that there exist three principal market drivers for NGV propagation. The price difference between natural gas and petroleum fuels (gasoline and diesel) appears to be the single most important NGV market driver. Secondly, cooperation between the various stakeholders such as government, vehicle and equipment manufacturers, the gas industry, and customers is important. Lastly, government involvement through a variety of policies is identified as a common requirement for NGV commercial growth.

On the other hand, limited number of fueling station due to either high cost or safety related regulation has been identified as the biggest stumbling block to NGV market growth. Other facts such as high initial costs of vehicles limited offer of OEM vehicles and lack of pipeline infrastructure have been identified as obstacles.

Korea is proud to become a good example of NGV related activities. Korea adopted R&D oriented approach, rather than market oriented approach, and succeeded in opening a market. Moreover, the principal driving force has been air quality preservation, rather than fuel cost saving, and emphasis has been placed on the replacement of heavy duty diesel-fueled vehicles with environmentally friendly NGVs. NGV was first introduced in 2000 and currently there are about 32,000 vehicles and about 180 refueling stations across the nation. It seems to be small in number of vehicles, but the amount of natural gas consumed by these vehicles is significant.

Vehicle types are bus, garbage truck and cars and fuel types are CNG, LNG and LNG dual fuel. Fig. 1 shows a number of NGV for each vehicle types. Most of vehicles are city bus rather than car and the growth has been continuously extended. Because of the policy oriented city bus due to weak infrastructure, the number of car is relatively small. The insufficient refueling station would be causing great inconvenience for car drivers. Recently,

natural gas fueled car has been increased due to fuel cost saving and will be expected to rapidly grow in near future.

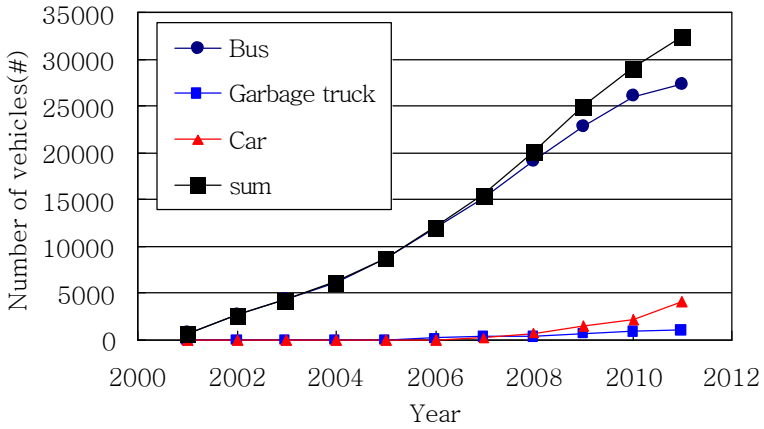


Fig. 1 NGV dissemination history in Korea

As the operation proceeds, the safety management of vehicles has been required to ensure the safety. So, re-inspection standards were established for vehicle and its equipments being operated such as CNG storage tank and safety valves for a certain period. Table 1 shows a re-inspection standard for CNG tanks installed in a bus. All storage tanks should be inspected every 3 years for safety check.

Table 1 CNG storage tank re-inspection standard in Korea

Re-inspection kind	cycle(year)	Remark
Fine re-inspection	3	Investigation under mounted on frame
Detail re-inspection	6	Investigation after separated on the frame

1.2 Refueling Infrastructure

There are three types of fueling stations in Korea such as stationary CNG system, LCNG system and LNG only system. CNG system including mother and daughter system is a fueling station which is installed in an area where pipeline is available. In an LCNG system, LNG stored in station tank, instead of pipeline gas, is pressurized and vaporized prior to feed into vehicles. The operation cost of LCNG station is lower compared to compressed natural gas station and LCNG station can provide both LNG and CNG. On the other hand, in case when only needed LNG fuel, LNG system is suitable for LNG vehicles purpose. Most of fueling stations in Korea are CNG and adopt cascade refueling method enabling very quick filling. A number of refueling stations are shown in Table 2 and Fig. 2 shows one of LCNG station in Pohang.

Table 2 Refueling stations in Korea

Stations	# of sites	remark
CNG	155	Public use: 173 Private:5
M&D	17	
LCNG	4	
LNG	2	
Total	178	

Fig. 2 LNG bus refueling scene in LCNG station(Pohang)

1.3 NGV Policy

The Korea's Ministry of Environment (MOE) has been in charge of NGV programs and various support policies - subsidies and loans, support for NGV operators and fueling station owners and tax exemption - have been come into effect by MOE. The target of MOE has been to ensure clean and comfortable air quality especially in urban area and emphasis has been placed on replacing diesel fueled city buses and garbage trucks with NGVs.

There are subsidizing programs to induce vehicle operators to purchase NGV. City bus operators and garbage truck owners who purchase NGV receive USD22,500 and USD60,000 per vehicle respectively from government. The size of subsidy is approximately the same as the price difference between diesel fueled vehicles and NGVs. The unit subsidies paid initially were decreased somewhat in the progress. Many local governments legislate against diesel buses and any new buses replacing exiting buses should be fueled by natural gas. There are also various tax exemption benefits for NGV.

To establish a nation wide natural gas fueling infrastructure, various incentives are given to fueling station business. There is support loan program for natural gas fueling station investors. Each station can get up to USD700,000 government loan at low interest rate. Fuel cost aid system guarantee at least USD0.12/m3 margin for station operators. If the price difference between diesel and natural gas is less than USD0.12/m3, government supports so that station operators can get least margin. Fuel cost aid system turns out to be a very powerful incentive for station investors. Corporation tax is exempted for installing a new fueling station. MOE provides incentives for car manufactures and local governments as well.

Next generation vehicle program is a government initiating R&D program in which many car manufactures and equipment suppliers are participating. The purpose of this program is to maintain a competitive edge in next generation low emission vehicles. Efforts to prepare the types of NGV satisfied EURO 6 and it is currently being underway to develop relating fueling system .

1.4 The Effect of NGV

Natural gas vehicles operated in metropolitan areas have improved the air quality. In particular, PM was greatly decreased during 10 years as shown in Fig. 3. PM in Seoul was reduced from 65μg/m3 in 2000 to 47μg/m3 in 2010. In addition, the NOx and CO were also decreased for same period. Seoul's air quality is still poor compared to other cities as shown in Fig. 4 and the extra effort should be made in order to improve further.

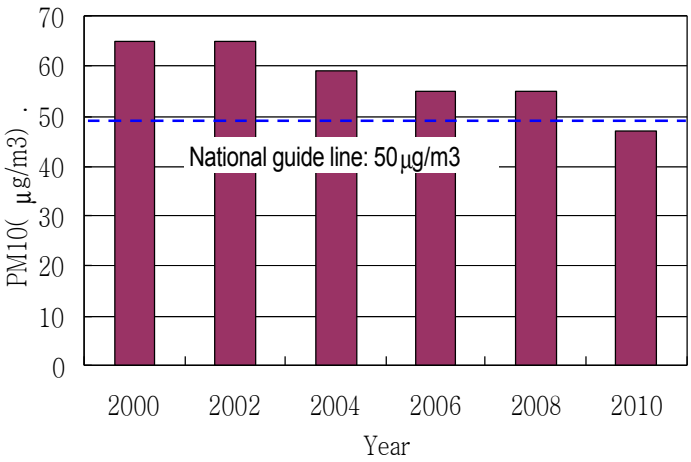


Fig. 3 History of PM reduction in Seoul, Korea

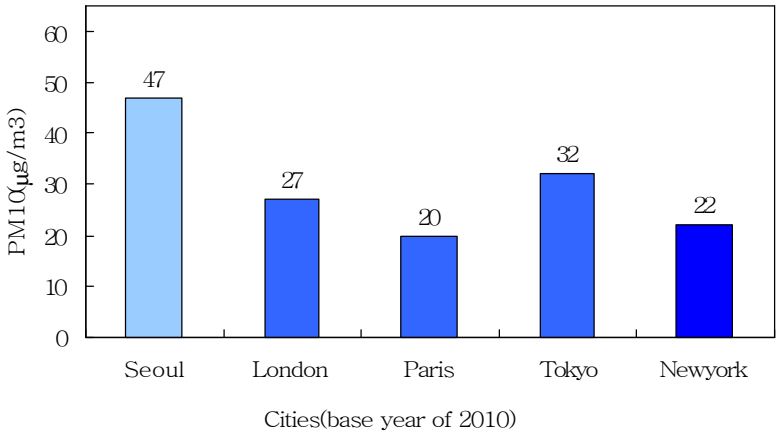


Fig. 4 Comparison of PM concentration among world cities

Vehicle emission standards have been step by step strengthened more. Fig. 5 shows a trend of European standards of HDV especially in terms of NOx and PM and it was announced to enforce EURO6 from 2014. In the case of Korea, EURO5 standards are being applied since 2010 and EURO 6 standards for CNG bus is scheduled to be in 2014 same as EU as shown in Fig. 6. Under these circumstances, the gas suppliers need to have an attention on the concern of automotive manufacturers and the trend of emission standards. Car manufacturers' interest is to meet emission standards only regardless of sources of fuel, therefore the gas supplier should have an continuous interest on these circumstance in order to survive mobile industry.

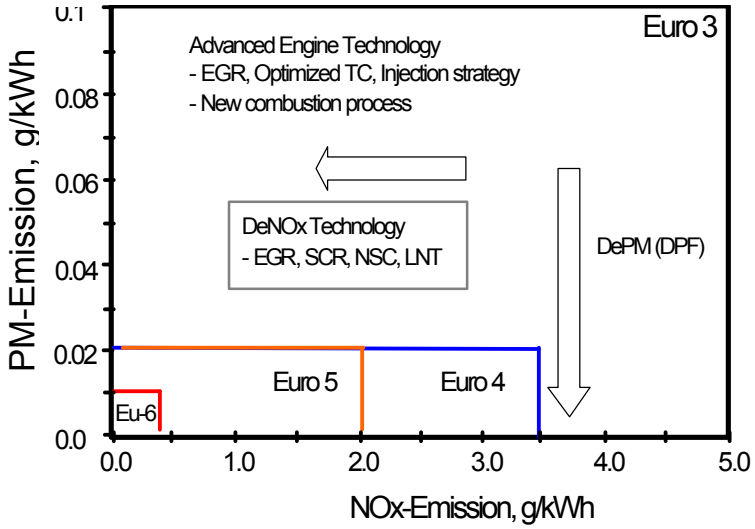


Fig. 5 EU emission standards of HDV

For natural gas vehicle, it still remains competitiveness when compared to liquid fuel due to clean and low-CO2 fuel characterestic, but if emission reduction efforts are not made hardly, the competitiveness can not be sustained in the future. To overcome these challenges, new technologies are needed and the HCNG technology is one of the ways. Hydrogen blended compressed natural gas(HCNG) vehicle has been developed in many countries because of very low emission and low CO_2 characteristics.

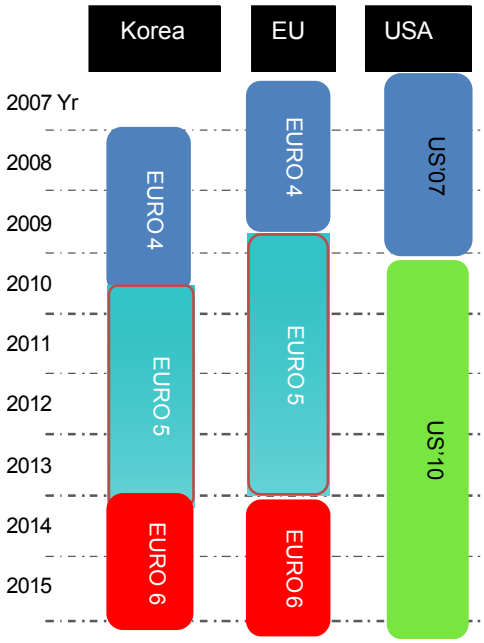


Fig. 6 Enforcing time schedule of emission standards

II. HCNG PROJECT IN KOREA

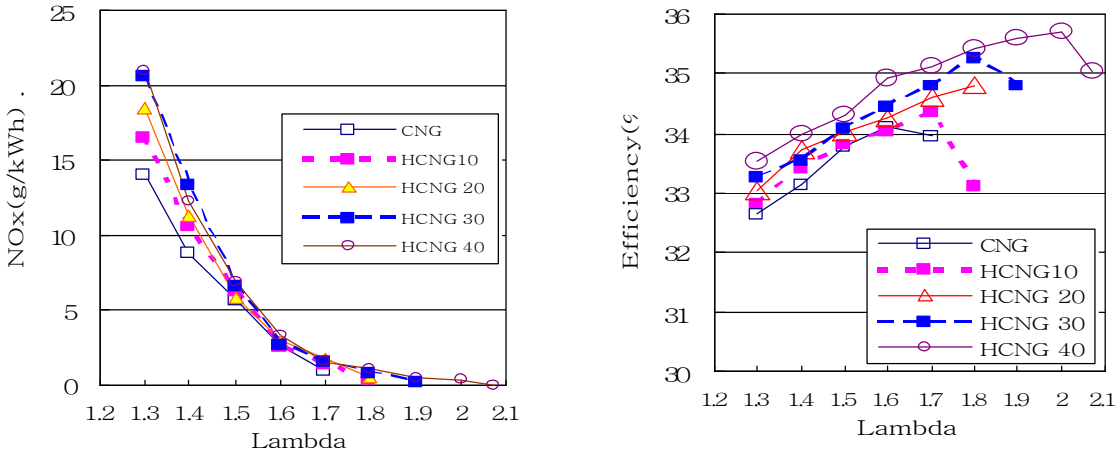
2.1 HCNG Concept

Physical and chemical characteristics of the HCNG fuel are shown in Table 3. As shown in this table, combustion potential of HCNG is higher than natural gas. As the hydrogen mixing volume increases, the flammable lean limit is also expanded as well as the burning rate is increased. So, engine efficiency is expected higher because of less ignition delay.

Table 3 Characteristics of hydrogen blended CNG fuels

Specifications		Natural gas	10%HCNG	20% HCNG	30% HCNG
Molecular weight(g/mole)		18.1	16.1	14.4	12.4
H/C ratio		3.7	3.9	4.2	4.5
Specific gravity		0.63	0.56	0.50	0.43
Heating value	High MJ/Nm3	44.2	41.2	38.1	34.9
	Low MJ/Nm3	40.2	36.4	33.3	29.5
Combustion potential(CP)		41.6	52.3	64.7	79.2
flammable limit		4.8~13.6	4.8~14.9	4.7~16.4	4.7~18.4

Especially, the characteristic of lean limit expansion and rapid combustion speed make the combustion temperature lower so that it provides fundamental reason of nitrogen oxide reduction. Therefore, NOx emission level can be effectively reduced by using HCNG technology.



(a) (b)

Fig. 7 (a) NOx emission and (b) engine efficiency due to A/F variations and change of hydrogen blending rate

Fig. 7 (a) and (b) show preliminary data obtained NOx emission and engine efficiency according to the fuel types and A/F conditions. The higher the hydrogen blend rate, the lower the NOx emission. Similar trend is shown in Fig. 6(b) between thermal efficiency and hydrogen blending rate. Another advantage of HCNG technology is reduction of CO2 emission. Because of high H/C ratio, CO2 saves more fuel used. As a global warming substance, CO2 should be controlled around the world. So, HCNG technology is effective on the reduction of NOx and CO2 as well.

On the other hand, HCNG technology have been demonstrated on a pilot scale in the United States and Europe. Significant reduction of NOx was confirmed through the demonstration. To commercialize the HCNG technology, the construction of the refueling infrastructure is reported as a key factor. However, it is required large investment and time consuming which make difficult to commercialize. Therefore, it should be noted that the cooperation between vehicle manufacture and fueling station parties is essential for the commercial success.

Table 4 Comparison of competitiveness among technologies

Techni Items	CNG Lean burn	HCNG Lean burn	CNG Stoichio	CNG Hybrid	Fuel Cell or Electric
after treatment	Urea-SCR DOC	DOC	3 way catalyst	HC-SCR DOC	-
sfc	△	○	▽	◎	◎
emission	○	○	○	○	◎
CO_2	△	○	▽	○	◎
durability	◎	◎	△	○	△
cost	△	◎	◎	X	X
infra	○	▽	◎	○	X
SCORE	19	23	18	21	17

X-more bad(0), ▽-bad(1), △-normal(2), ○-good(4), ◎-very good(5)

Table 4 shows the existing technologies which are expected to satisfy EURO 6 standard and compared the features with major items such as economic side, technical issues and infra conditions. In this analysis HCNG technology is the best way to cope with EURO 6 and

has advantages on the cost and the durability. Stoichiometric combustion technology that uses three-way catalyst has a problem of the high combustion temperature so that the piston and the exhaust system should be modified to ensure durability. This technology gets relatively worse fuel economy and CO2 than lean burn systems. The cases of fuel cell or electric bus have superior characteristics both emission and CO2 but the biggest stumbling blocks are very high price and poor infrastructure.

2.2 HCNG Project Overview

In order to develop the HCNG technology a following plan is in progress. This project is supported by "ECO-STAR PROJECT" generated by the Ministry of Environment(MOE). The project was organized in the form of a consortium which was composed of infrastructure, standard, engine and vehicle groups. Starting in 2011, five- year period is expected to develop and progress is going to organized by the Korea Gas Corporation(KOGAS). The table 5 is the overview of the project and Fig. 8 shows a role of the consortium groups.

Table 5 HCNG project overview

Program	ECO-STAR PROJECT
Title	A Development of engine and refuelling station for HCNG fueled city bus
Period	Aug. 2011 ~ Apirl 2016
Goal	HCNG bus and infrastructure demonstration and ready for commercialization
Budget	13 mil $

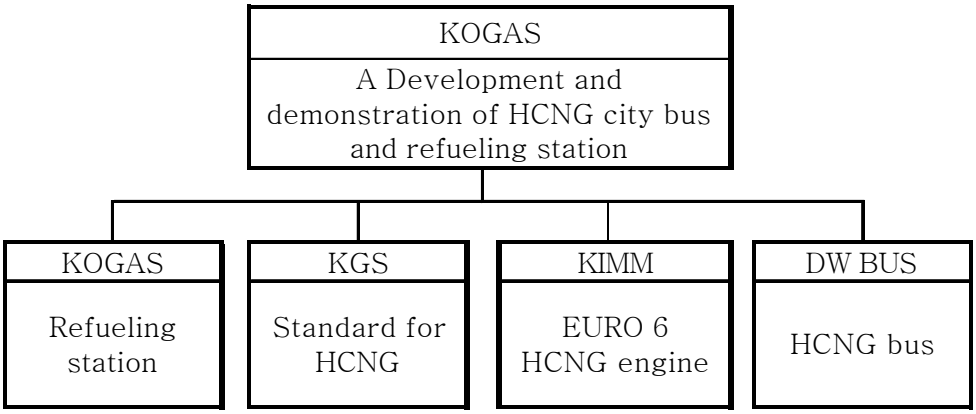


Fig. 8 A role of the groups in HCNG consortium.

2.3 HCNG Infrastructure Strategy

Hydrogen supply systems could be applied on HCNG station, and are identified by two ways . One way is to provide on-site by reforming a hydrocarbon fuel and the other is the off-site type by transportation of hydrogen already produced. Natural gas steam reforming method can be applied to the existing CNG stations. In Korea, the CNG stations are being operated throughout the country. If we take advantage of CNG stations for building HCNG infrastructure, this way is more effective to construct without any worry about NIMBY problem. And by hydrogen reformer scale up in the HCNG station, hydrogen infrastructure is expected to be built naturally in the futue. Therefore, HCNG station will be the best way to build in the CNG station in the form of complex station.

III. SUMMARY AND CONCLUSIONS

Regarding the status of natural gas vehicle in Korea is described. Since the market situation could be strongly affected by fuel price and environment policies, government level involvement is essential. Various support policies such as subsidies and loans, support for NGV operators and fueling station owners and tax benefits are played as an important role. In Korea, the spread of NGV has contributed to air quality a lot. PM10 concentration was decreased from 65μg/m3 in 2000 to 47μg/m3 in 2011. Continuous efforts are being required to make more comfortable air quality.

Also, to cope with more strong regulation level in transportation industry, NGV parties should make strong efforts on new technology to have more competitiveness than other fuels. A HCNG project is being performed in Korea since last year. A consortium group is composed of gas supplier group, standard organizing group and engine and bus group respectively. To supply HCNG fuel, we are looking for ways to utilize existing CNG stations which can provide hydrogen by reforming process. By developing HCNG technology, it expects not only to ready EURO 6 regulation but also to highly contribute to NGV industry.

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